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GB 1359737
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(54) DC motor drive circuit arrangements

(57) A brushless dc motor driving circuit arrangement comprises a variable constant current source A2 connected in series with motor windings L1, L2, L3. The motor torque, which is proportional to motor currents, is adjusted by controlling the current value of the variable constant current source A2. A supply voltage control loop may also be provided, so that power loss at the variable constant current source becomes a minimum. (Fig. 11, not shown).

FIG. 5

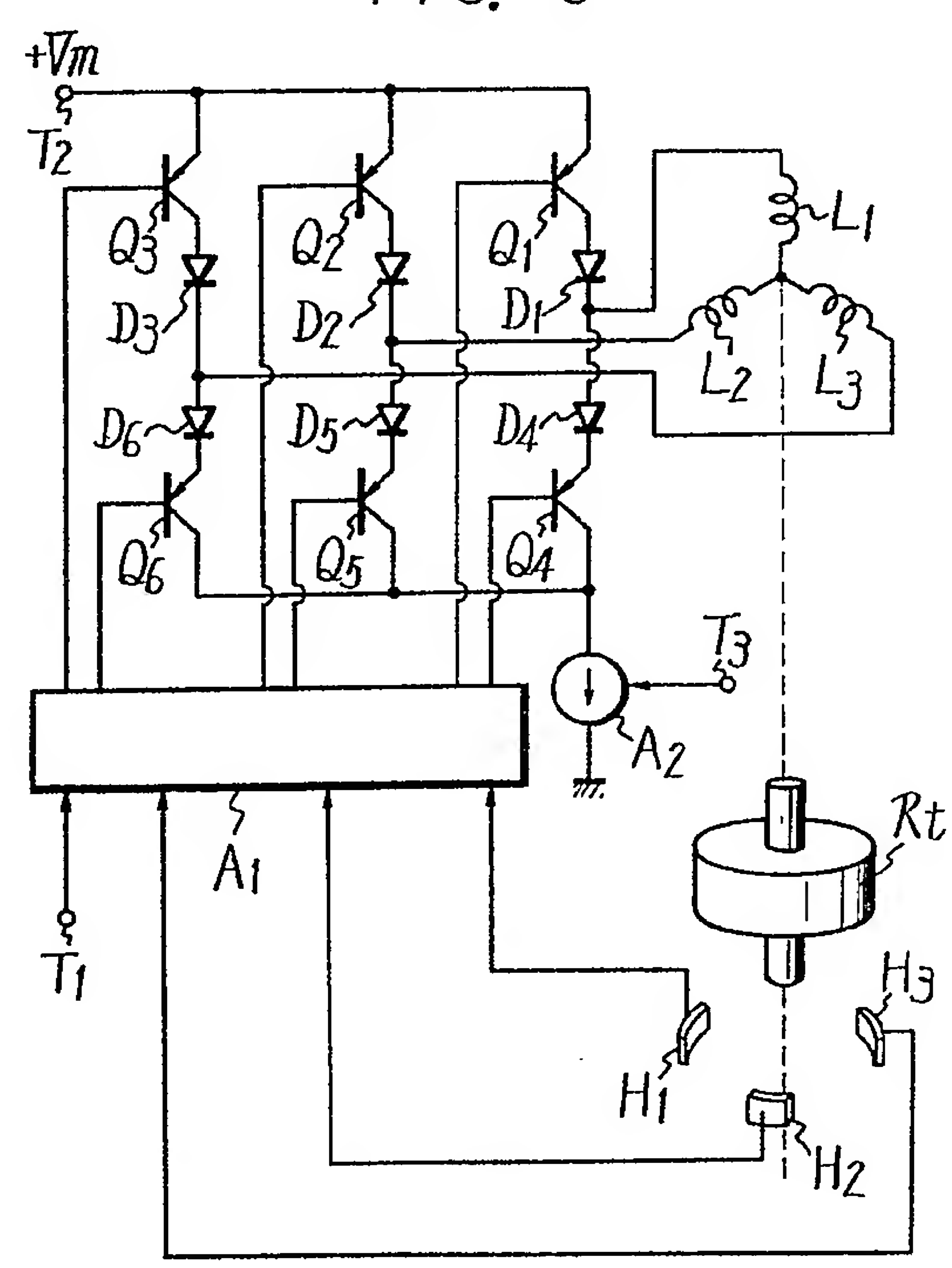

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FIG. 1

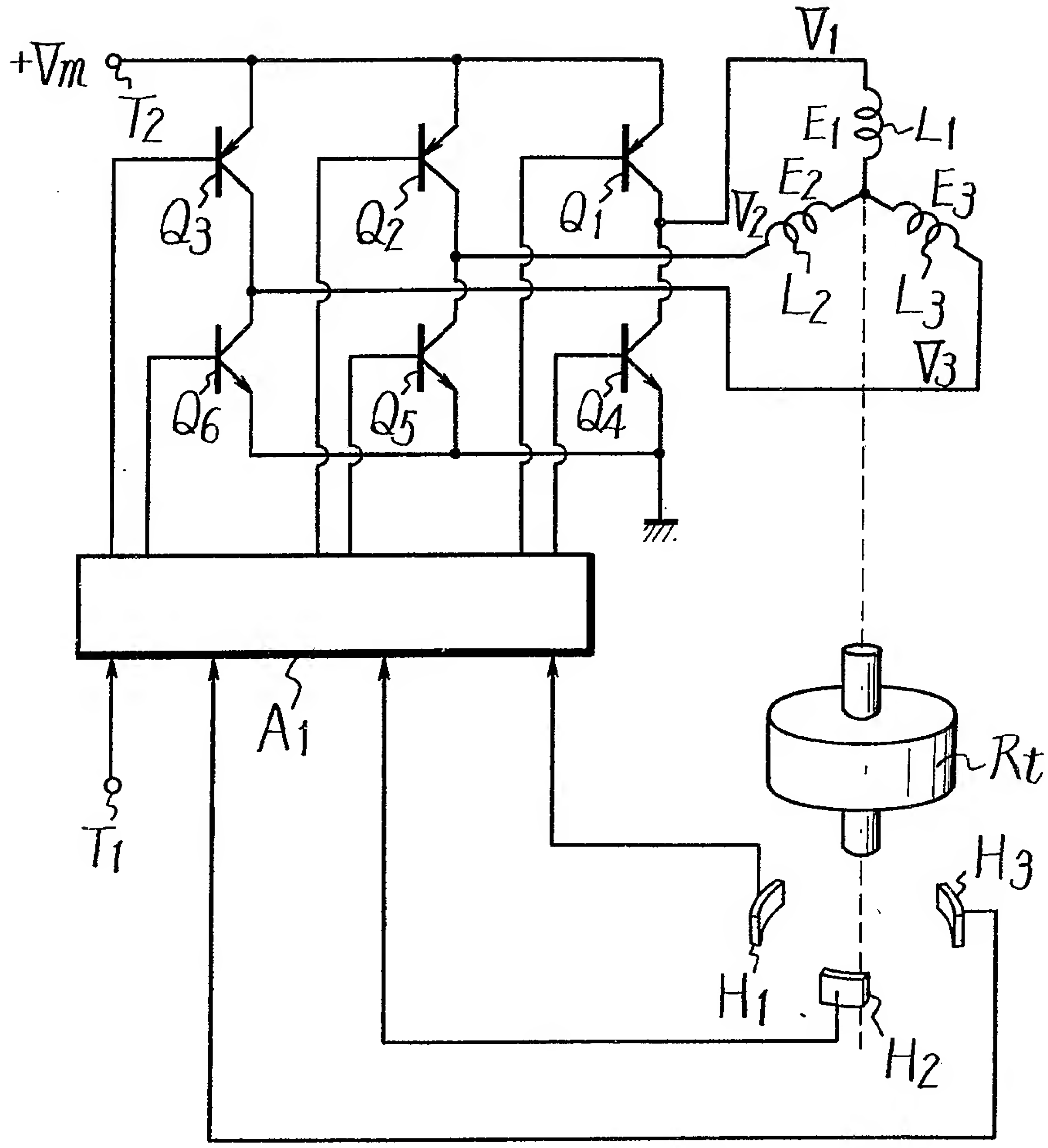


FIG. 2A

FIG. 2B

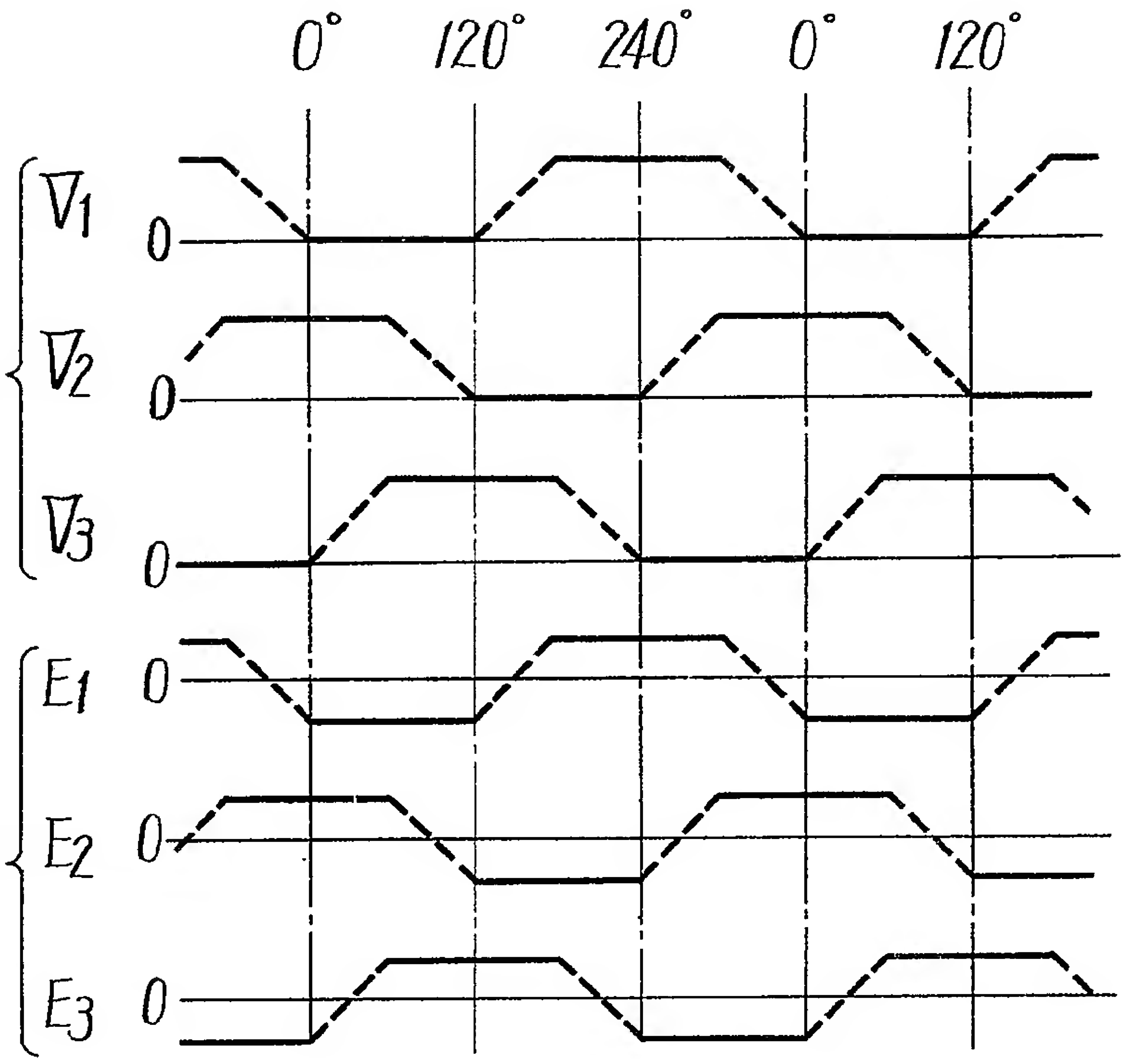


FIG. 3

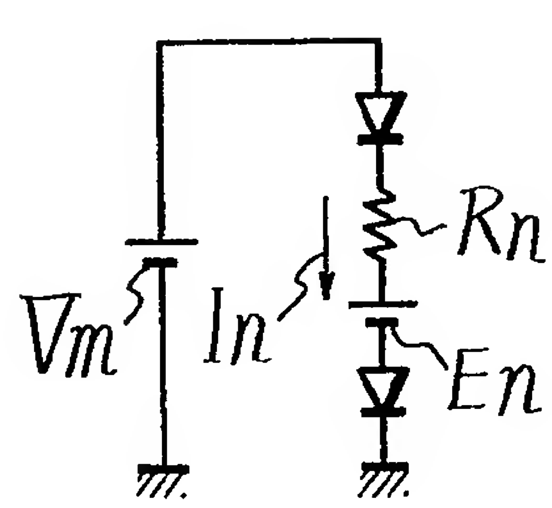


FIG. 4

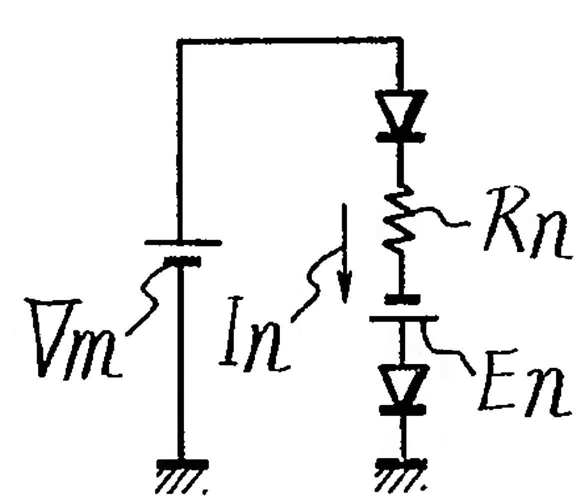
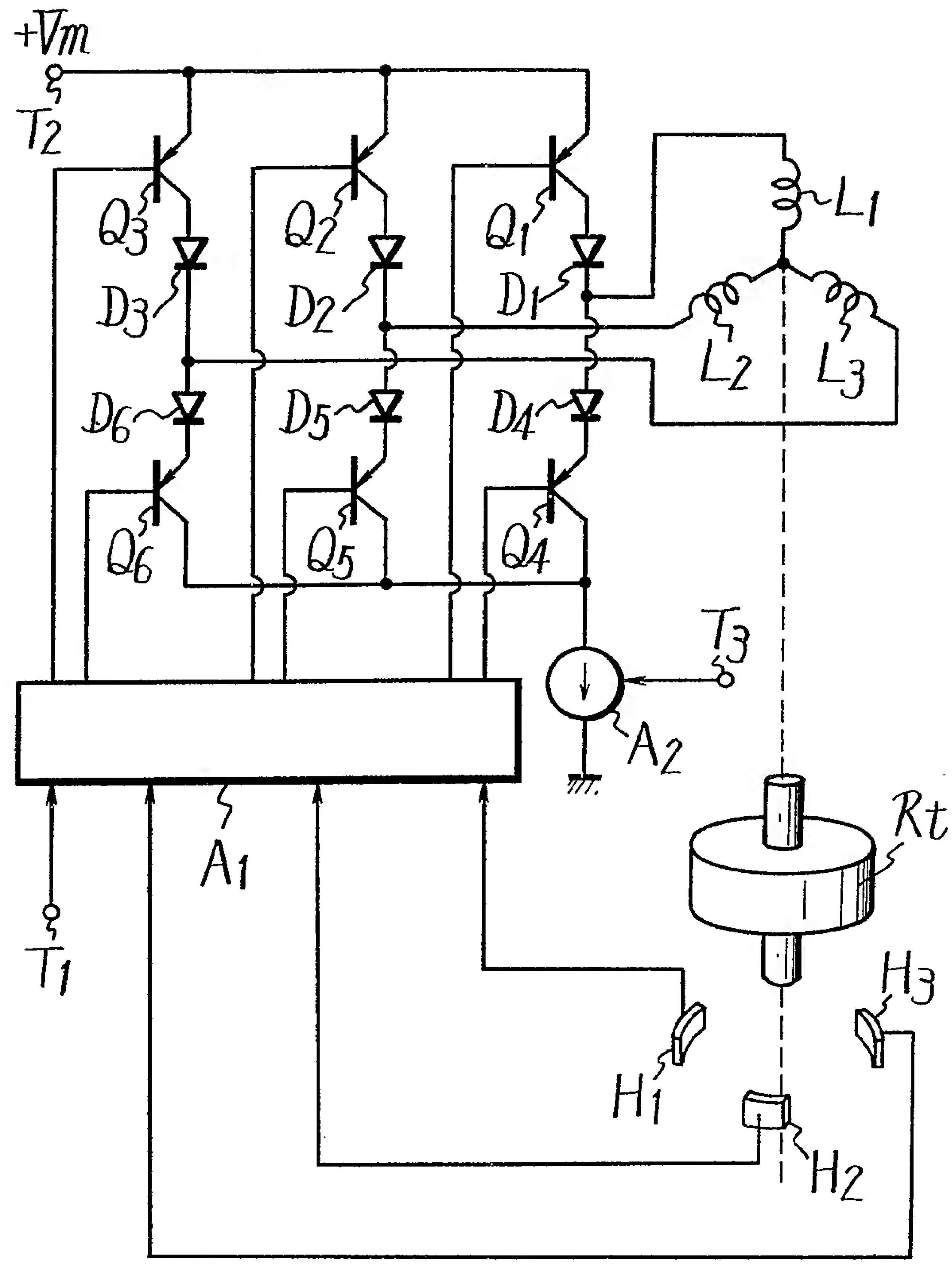


FIG. 5



+Vm
T2
Q3
Q2
Q1
D3
D2
D1
L1
L2
L3
D6
D5
D4
Q6
Q5
Q4
T3
A2
A1
T1
Rt
H1
H2
H3

FIG. 6

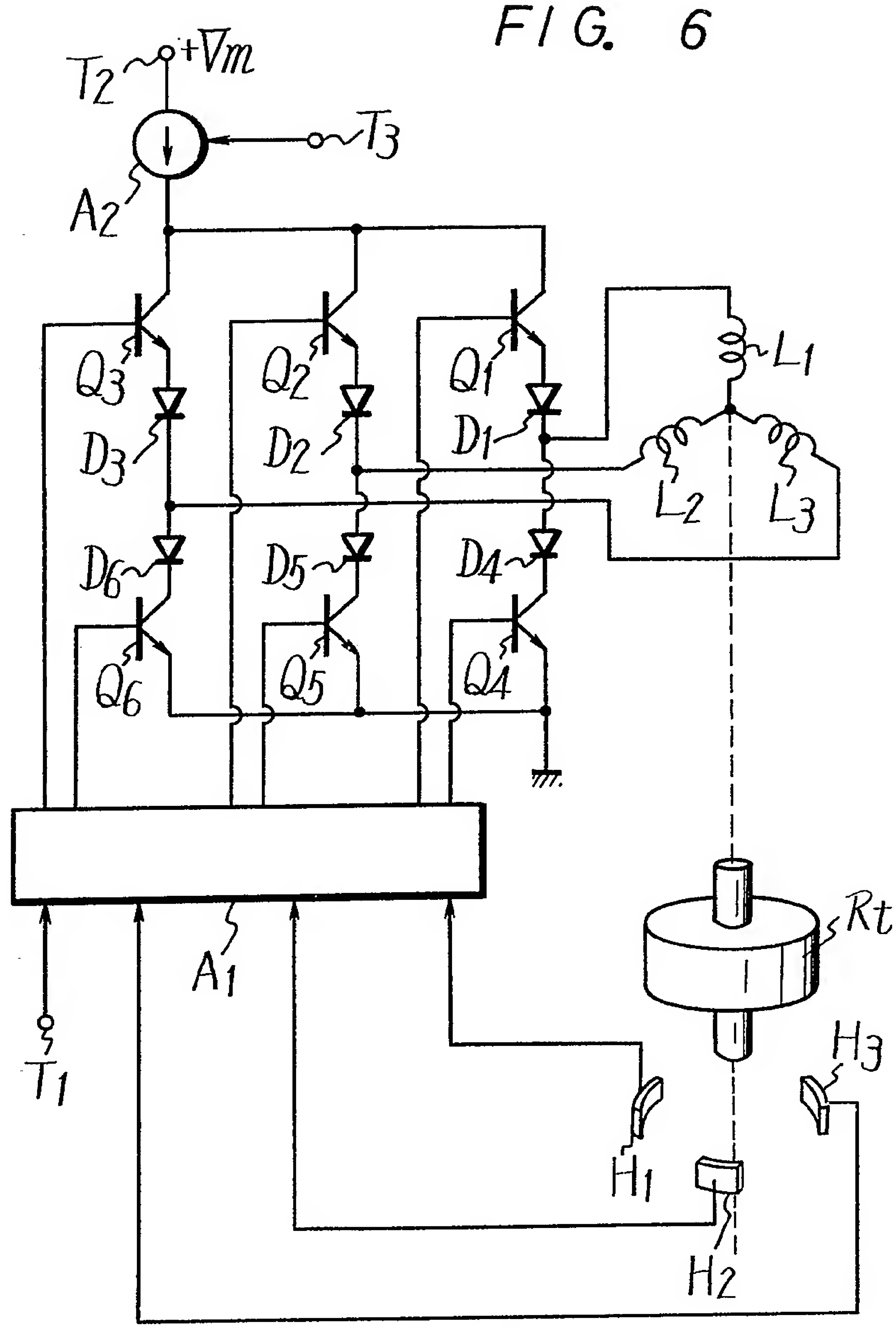
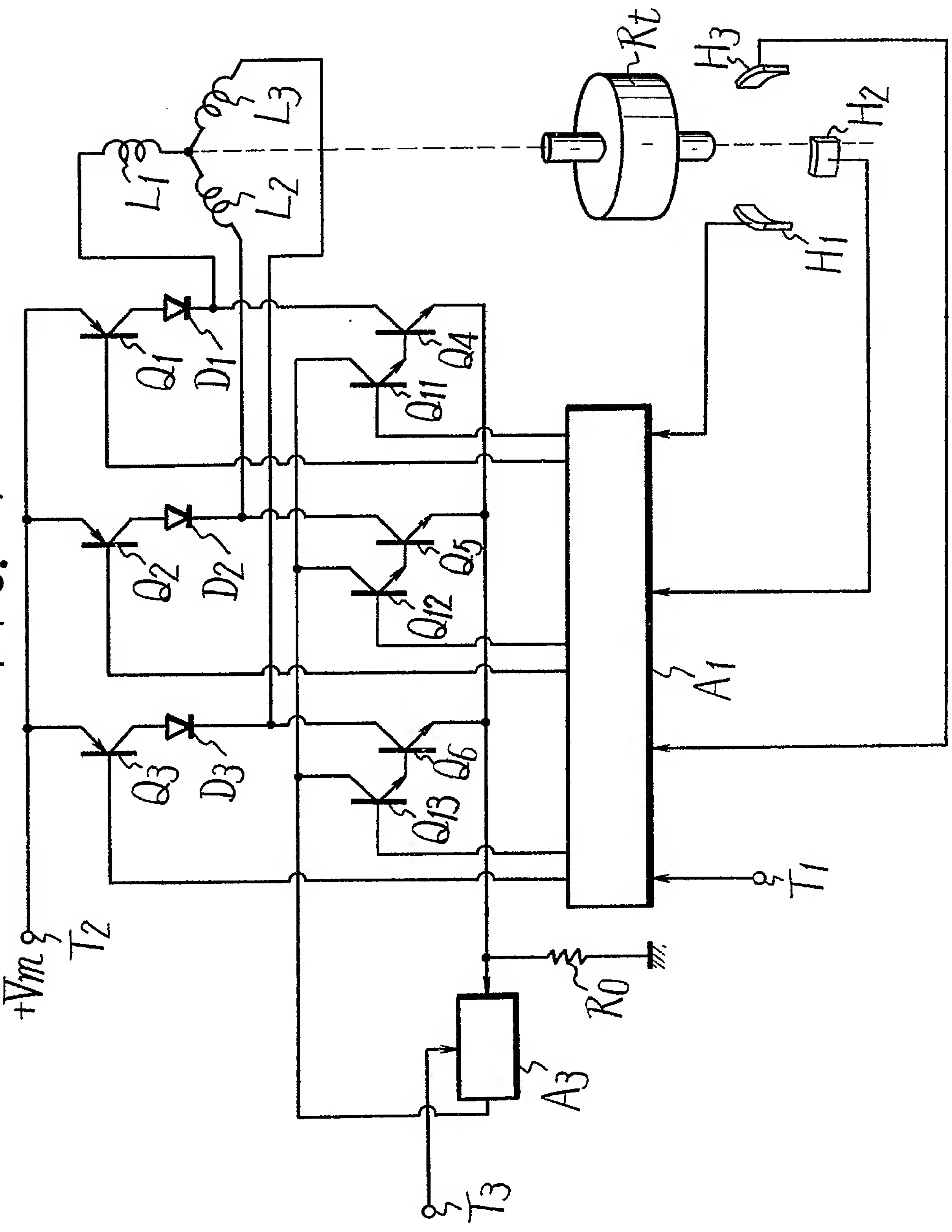

T2
+Vm
T3
A2
Q3
Q2
Q1
L1
D3
D2
D1
L2
L3
D6
D5
D4
Q6
Q5
Q4
Rt
A1
T1
H3
H1
H2

FIG. 7


Rt
H3
L3
H2
L1
L2
H1
Q1
D1
Q11
Q4
Q2
D2
Q12
Q5
A1
Q3
D3
Q13
Q6
T1
+Vm
T2
R0
A3
T3

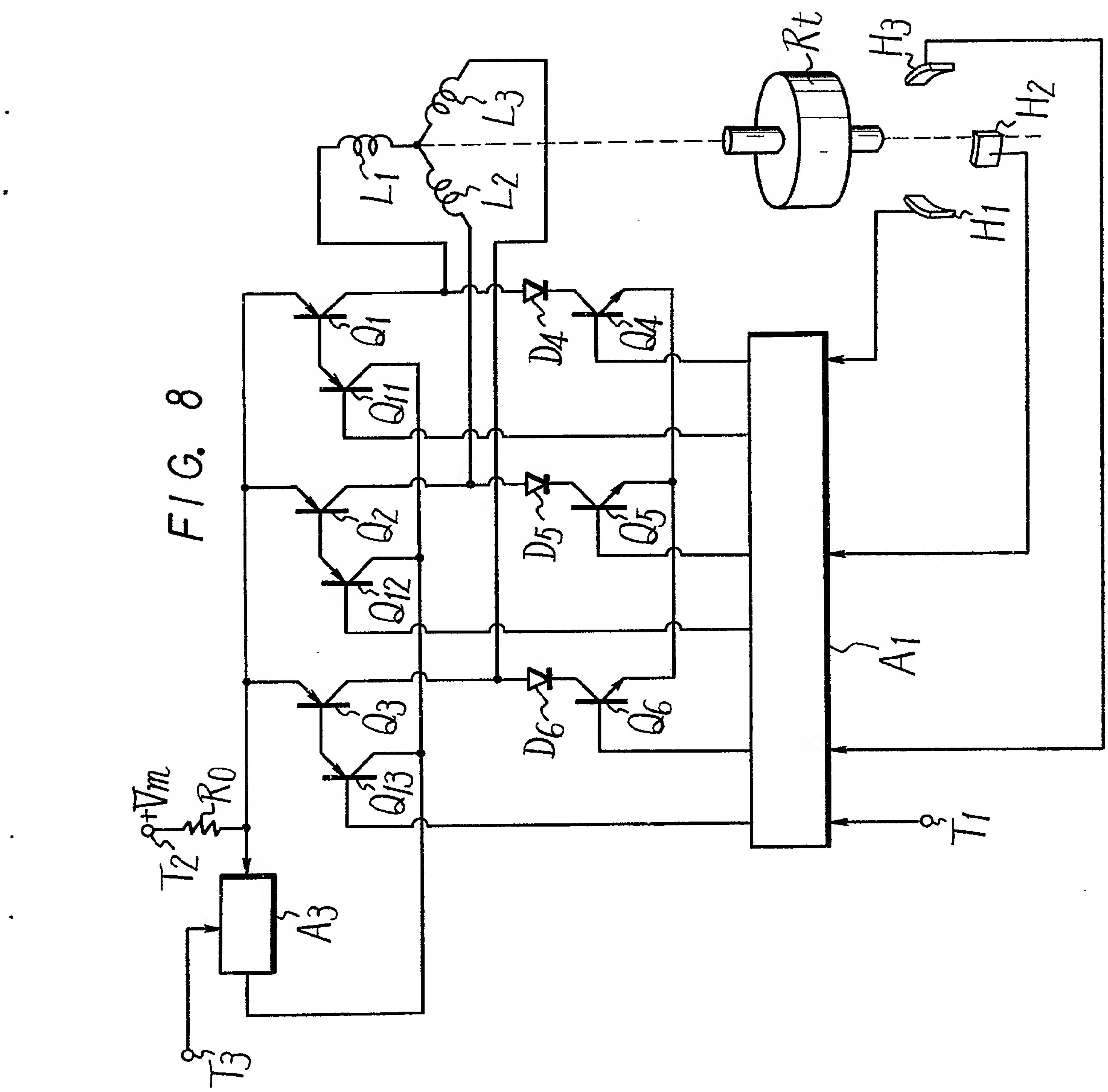

Rt
L1
L2
L3
H1
H2
H3
Q1
Q2
Q3
Q4
Q5
Q6
Q11
Q12
Q13
D4
D5
D6
A1
A3
+Vm
R0
T1
T2
T3

FIG. 8

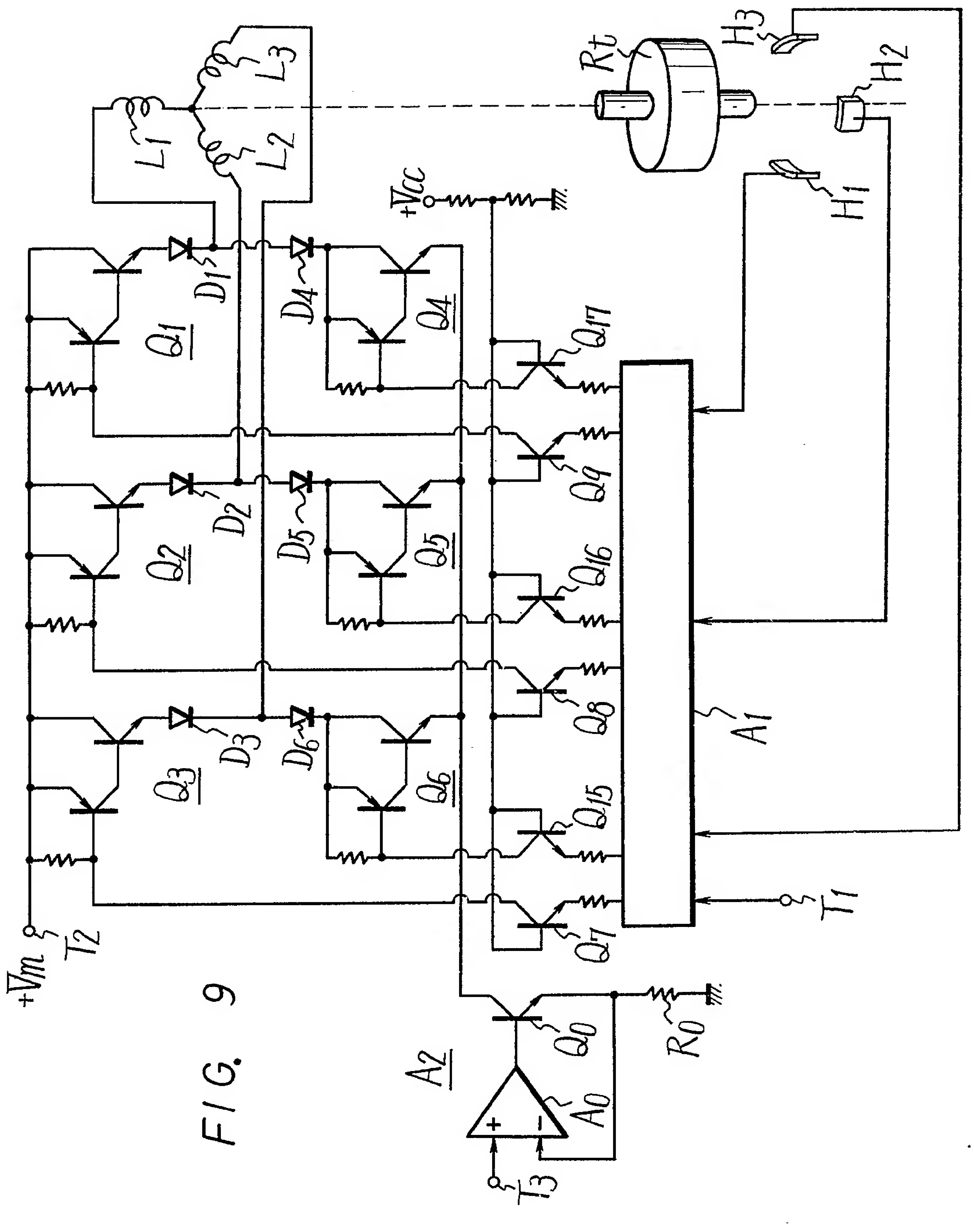
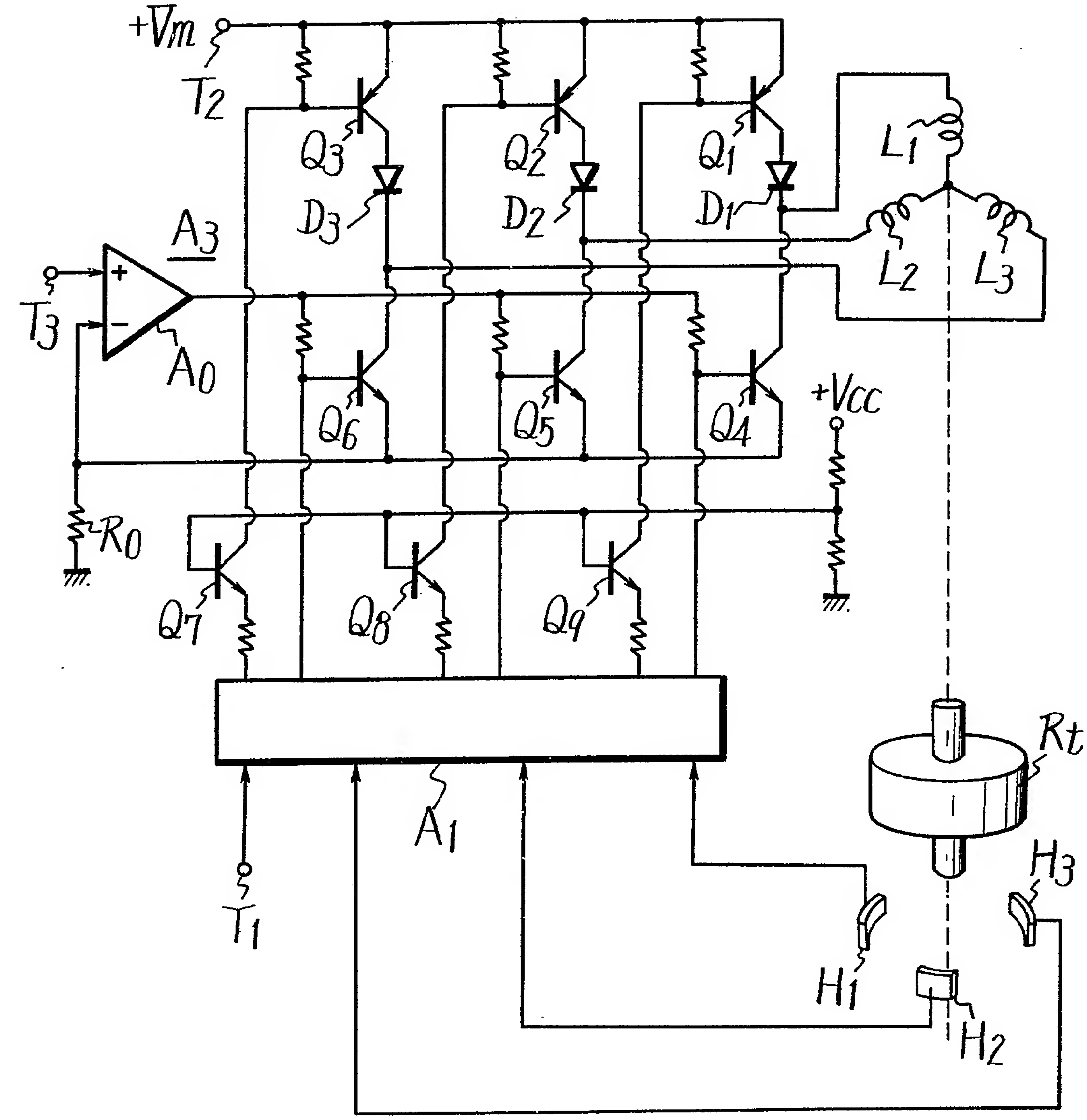

Rt
L1
L2
L3
H1
H2
H3
+Vcc
+Vm
T1
T2
T3
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
Q9
Q15
Q16
Q17
Q0
D1
D2
D3
D4
D5
D6
A1
A2
A0
R0

FIG. 9

FIG. 10


+Vm
T2
Q3
Q2
Q1
L1
D3
D2
D1
L2
L3
A3
T3
A0
Q6
Q5
Q4
+Vcc
R0
Q7
Q8
Q9
Rt
A1
H3
T1
H1
H2

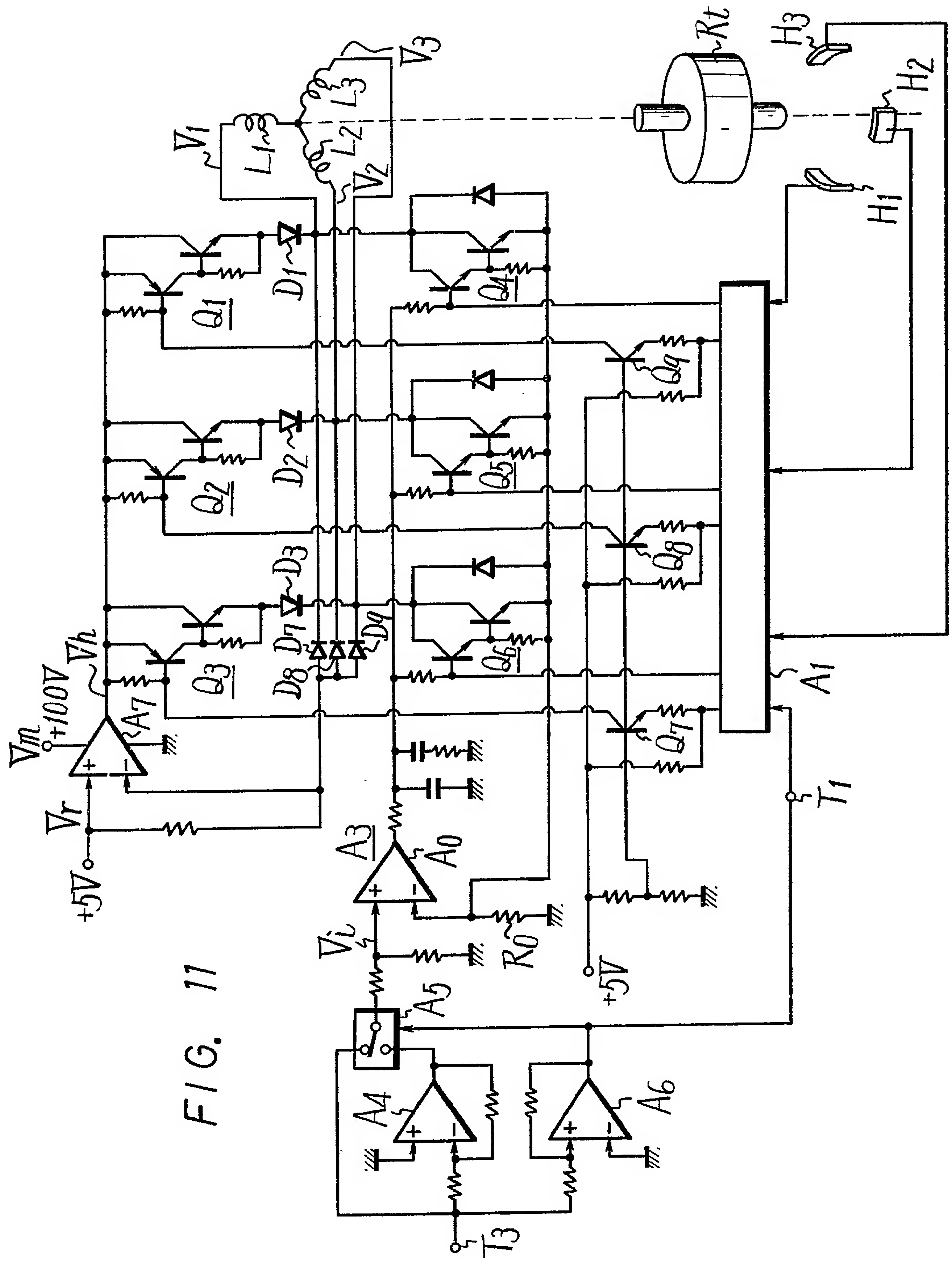

V1
V2
V3
L1
L2
L3
Rt
H1
H2
H3
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
Q9
D1
D2
D3
D7
D8
D9
A0
A1
A3
A4
A5
A6
A7
Vm
+100V
Vh
Vr
+5V
Vi
R0
+5V
T1
T3

FIG. 11

FIG. 12A

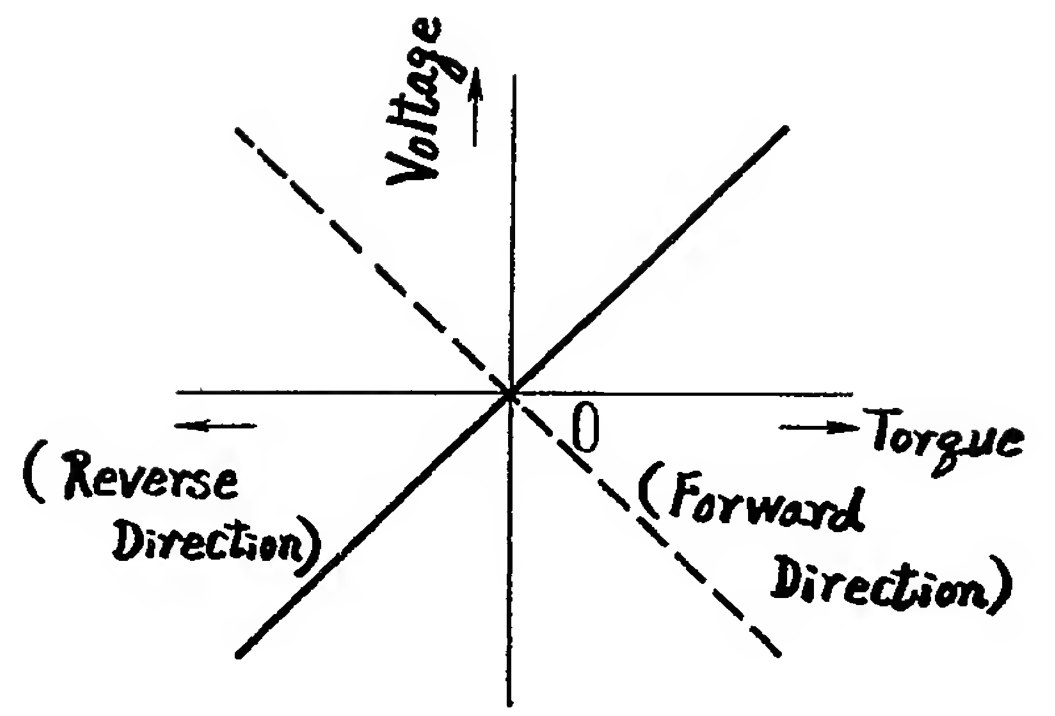


FIG. 12B

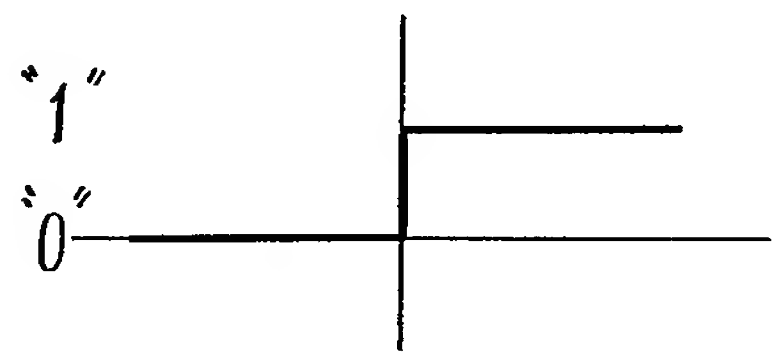


FIG. 12C

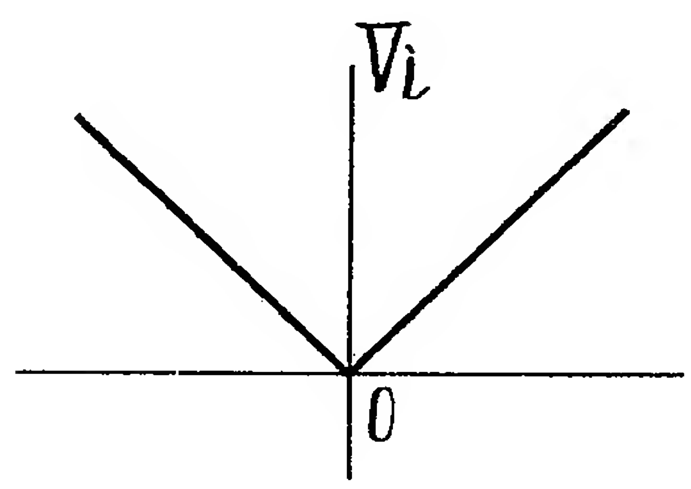


FIG. 13

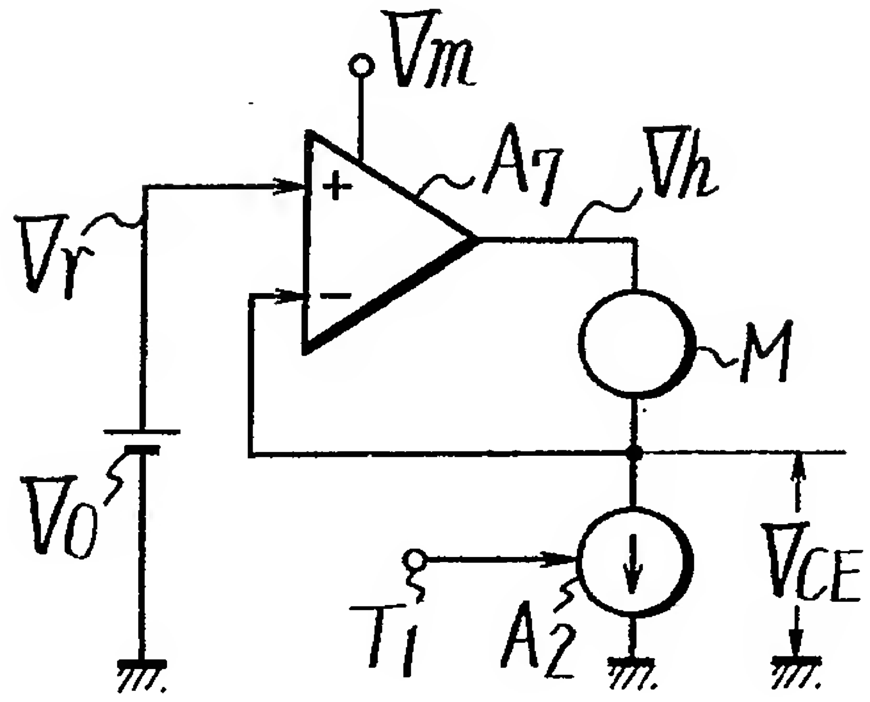
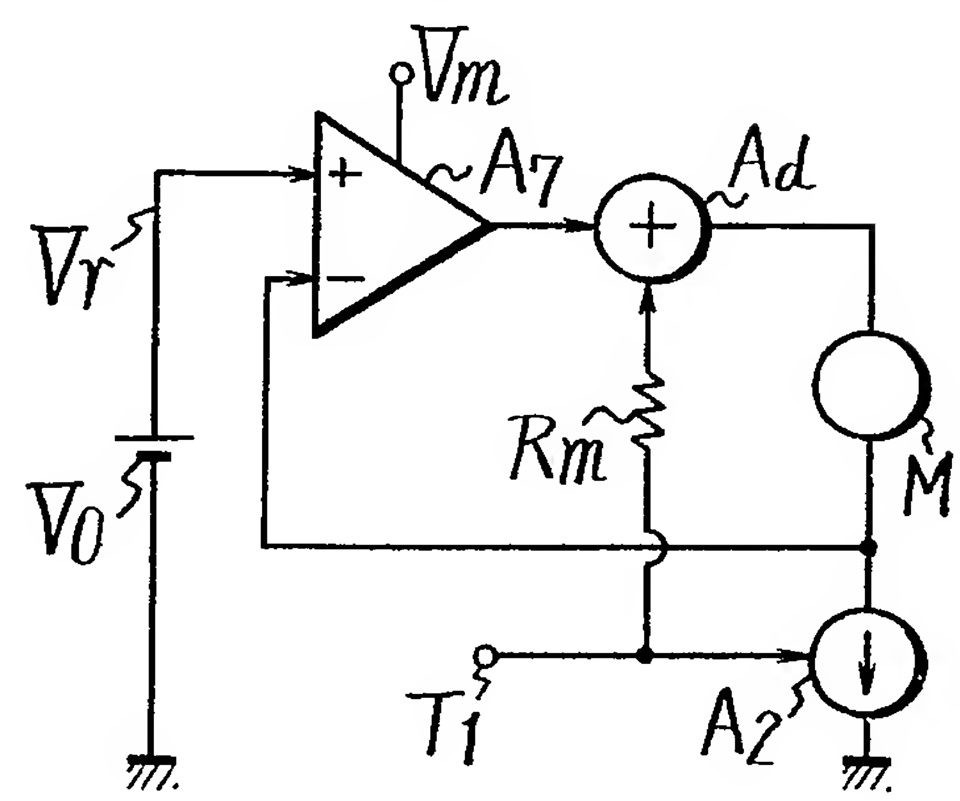


FIG. 14



SPECIFICATION

Dc motor drive circuit arrangements

This invention relates to dc motor drive circuit arrangements.

An arrangement comprising a brushless dc motor and its drive circuit is illustrated in Figure 1 of the accompanying drawings to which reference is now made. The motor comprises stator windings L1, L2 and L3 disposed at angular intervals of 120°, a permanent magnet rotor Rt, and detecting devices H1, H2 and H3 each of which is, for example, a Hall effect device. The devices H1 to H3 are also disposed at angular intervals of 120° opposite to the rotor Rt to detect the rotational phase of the rotor Rt. The outputs of the devices H1 to H3 are supplied to a switching logic control circuit A1, which performs cyclic switching control of output switching transistors Q1 to Q6.

Thus, the windings L1 to L3 are supplied with drive pulses V1 to V3 as shown in Figure 2A of the accompanying drawings, and the rotor Rt rotates in a forward direction in this case. At this time, the windings L1 to L3 are also generating reverse electromotive voltages E1 to E3 as shown in Figure 2B of the accompanying drawings. When the logic level at a terminal T1 of the control circuit A1 is changed, the drive pulse V2 is supplied to the winding L3 and the drive pulse V3 is supplied to the winding L2, so that the motor rotates in the reverse direction.

When such a motor accelerates and decelerates over a wide range, for example, from 1000 rpm in the forward direction to 1000 rpm in the reverse direction, or when the motor is employed in the reel drive system of a video tape recorder (VTR) to set a tape tension or to accelerate and decelerate a tape speed, the torque of the motor must be linearly controlled during the braking operation as well as during the driving operation.

However, in the conventional arrangement of Figure 1, the torque cannot be controlled to a desired value. In other words, if the transistors Q1 to Q6 are each regarded as a diode, that is a unidirectional device, the equivalent circuit during the driving operation is as shown in Figure 3 of the accompanying drawings, and the equivalent circuit during the braking operation is as shown in Figure 4 of the accompanying drawings, where Rn is a resistance of a stator winding, In is a current flowing through this stator winding, and Vm is a supply voltage. Accordingly, during the braking operation (Figure 4), even although the supply voltage Vm is zero, the current In flows due to a reverse electromotive voltage En, to produce a torque corresponding to the current In, so that the torque cannot be controlled to a desired value.

According to the present invention there is provided a dc motor drive circuit arrangement for controlling the torque of a dc motor, the circuit comprising:

a first power supply terminal;

a second power supply terminal;

motor windings interconnected between said first and second power supply terminals for being supplied with a driving power therefrom; and

a variable constant current circuit interposed between said motor windings and one of said first and second power supply terminals for controlling the torque of said dc motor in response to a control signal supplied to said variable constant current circuit.

The invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a circuit diagram showing a conventional brushless dc motor drive circuit arrangement;

Figures 2A and 2B are waveform diagrams for explaining the operation of the arrangement of Figure 1;

Figures 3 and 4 show equivalent circuits of the arrangement of Figure 1;

Figures 5 to 8 are circuit diagrams of respective embodiments of dc motor drive circuit arrangements according to the invention;

Figures 9 and 10 are circuit diagrams showing more detailed versions of the arrangements of Figures 5 and 7, respectively;

Figure 11 is a circuit diagram showing a more practical embodiment of dc motor drive circuit arrangement according to the invention;

Figures 12A, 12B and 12C are voltage/torque characteristics used for explaining the arrangement of Figure 11; and

Figures 13 and 14 show additional circuits of the arrangement of Figure 11.

In the arrangement of Figure 5, between a power supply terminal T2 of dc voltage Vm and ground is connected a series circuit of the emitter-collector path of a transistor Q1, diodes D1 and D4, the emitter-collector path of a transistor Q4, and a variable constant current circuit A2 of a current-sink type. Also, a series circuit of a transistor Q2, diodes D2 and D5, and a transistor Q5, and a series circuit of a transistor Q3, diodes D3 and D6, and a transistor Q6 are respectively connected in parallel with the series circuit of the transistor Q1, the diodes D1 and D4, and the transistor Q4. In addition, between respective connection points of the diodes D1 and D4, D2 and D5, and D3 and D6 are connected stator windings L1 to L3 of a motor. The variable constant current circuit A2 is controlled in current value by a control signal fed from the terminal T3.

With this arrangement, currents I1 to I3 flowing through the windings L1 to L3 are to be absorbed into the constant current circuit A2 in sequence, so that these currents can be controlled by the constant current circuit A2. Accordingly, the motor torque can be freely and linearly controlled by changing the constant current circuit A2.

The diodes D1 to D6 are used to protect the transistors A1 to A6 against respective base-emitter breakdown voltages.

In the arrangement of Figure 6, the constant current circuit A2 is of a current-source type and connected to the hot end of the motor windings.

In the arrangement of Figure 7, the transistors

Q4 to Q6 are biased to operate in class-A mode and serve as a switching device as well as the constant current circuit A2. Thus the control circuit A1 functions to control on-and-off operation of the transistors Q11 to Q13. The motor current In is detected by a resistor Ro and a detected output therefrom is fed to a comparator A3 where it is compared with the control signal from the terminal 3. Then, a compared output of the comparator A3 is supplied through the transistors Q11 to Q13 to the transistors Q4 to Q6, so that the transistors Q4 to Q6 may operate as the constant current circuit A2.

Because the transistors Q4 to Q6 perform the function of the switching device as well as that of the constant current circuit, the total cost is reduced. Also, each of the transistors Q4 to Q6 operates as the constant current circuit for only one third of the time period, so that each transistor Q4 to Q6 generates less heat.

In the arrangement of Figure 8, the transistors Q1 to Q3 correspond to the transistors Q4 to Q6 of Figure 7, and operate as constant current circuits as well as a switching circuit.

Figure 9 shows a practical circuit example corresponding to the arrangement of Figure 5. In this arrangement, the transistors Q1 to Q6 are each connected in Darlington configuration, and the constant current circuit A2 is formed of an operational amplifier Ao, an output transistor Qo and a current detecting resistor Ro. Accordingly, if the control voltage at the terminal T3 is changed, the collector current of the transistor Qo is changed so as freely to control the motor torque in accordance with the control voltage.

Transistors Q7 to Q9 and Q15 to Q17 are switching buffer transistors each controlled from the emitter side thereof.

Figure 10 shows a practical circuit example corresponding to the arrangement of Figure 7. In this circuit, the comparator A3 is formed of the operational amplifier Ao and the current detecting resistor Ro.

Figure 11 shows a practical circuit example which is actually designed for a reel motor of a VTR. In the arrangement of Figure 11, dynamic control of a supply voltage to the motor is also carried out. Since the constant current circuit A2 connected in series with the dc motor is arranged to utilize the collector-emitter path of a transistor to generate a constant current, at least a voltage drop of the collector-emitter voltage VcE causes a power loss by an amount of the product of its dropped voltage VcE and motor current. In order to fix the above power loss to a minimum value, the arrangement of Figure 11 uses an additional circuit as shown in Figure 13 or 14.

In Figure 13, an operational amplifier A7 is provided and a reference voltage Vr is fed to the amplifier A7 at its non-inverting input and from the voltage source Vo. The motor M and the constant current circuit A2 are connected in series between the output end of the amplifier A7 and ground, and the connection point between the motor M and the constant current circuit A2 is connected to the inverting input end of the amplifier A7.

With this construction, a current flowing through the motor M is determined by the constant current circuit A2 and hence the torque of the motor M can be freely controlled by the control voltage from the terminal T1. In this case, the voltage VcE dropped across the constant current circuit A2 is compared with the reference voltage Vr in the operational amplifier A7 and the compared output Vh therefrom is supplied to the motor M so that the VcE is equal to Vr is obtained. Accordingly, if the reference voltage Vr can be held to the minimum value required for a constant current transistor to operate, the dropped voltage VcE can be made small, with the constant current transistor being kept in a normal operating state. As a result, the addition of the above circuit makes it possible freely to control the torque of the dc motor and also to reduce its power loss.

In the circuit of Figure 14, an adder Ad is provided between the output end of the operational amplifier A7 and the motor M, and the control voltage from the terminal T1 is supplied through a resistor Rm to the adder Ad. The value of the resistor Rm is made equal to the dc resistance of the motor M. Accordingly, in this case, the dc resistance of the motor M is compensated for by the resistor Rm, so that the control voltage from the terminal T1 can widely control the torque of the motor M.

In order to perform the above operation in the circuit of Figure 11, the operational amplifier A7 is provided and a control loop is formed through diodes D7, D8 and D9. Thus the operating voltages of the transistors Q4 to Q6 are fed back to the operational amplifier A7 and the required minimum voltage is supplied to the motor circuit.

The circuit of Figure 11 also includes a comparator A6, an operational amplifier A4 and a switching circuit A5 for bidirectional control. That is to say, the terminal T3 is supplied with a control voltage which is varied in polarity and level according to the torque required, as shown in Figure 12a by a solid line, and this control voltage is supplied to the operational amplifier A4 to produce a control voltage which is changed in a complementary manner to the original control voltage as shown in Figure 12A by a dotted line. These control voltages are supplied to the switching circuit A5. The control voltage from the terminal T3 is also supplied to the comparator A6 where it is converted into a signal which is varied in level according to the direction of torque as shown in Figure 12B, and this signal is supplied to the switch circuit A5 as its control signal so that a dc voltage having a level corresponding to the absolute value of torque as shown in Figure 12C is derived from the switching circuit A5. The dc voltage is supplied to the operational amplifier A3 for motor torque control.

The output voltage of the comparator A6 is also supplied to the terminal T1 as a signal for controlling the direction of the torque (rotation).

Moreover, the operational amplifier A7

performs control of the motor drive voltage described in Figure 12, to form a motor drive circuit of high efficiency.

CLAIMS

1. A dc motor drive circuit arrangement for controlling the torque of a dc motor, the circuit comprising:

a first power supply terminal;

a second power supply terminal;

motor windings interconnected between said first and second power supply terminals for being supplied with a driving power therefrom; and

a variable constant current circuit interposed between said motor windings and one of said first and second power supply terminals for controlling the torque of said dc motor in response to a control signal supplied to said variable constant current circuit.

2. An arrangement according to claim 1 further comprising a detecting circuit connected to said variable constant current circuit for detecting voltage drops across said constant current circuit, and a power supply control circuit connected to said detecting circuit for regulating supply voltage between said first and second power supply terminals to be a predetermined value.

3. An arrangement according to claim 1 wherein said dc motor is a brushless motor which includes a plurality fo windings and position detectors, and there is a switching circuit associated with said windings to switch the driving power to said windings in response to outputs from said position detectors for driving said motor in foward and reverse directions.

4. An arrangement according to claim 3 wherein said switching circuit includes pairs of switching devices connected in series, and said windings are connected to junction points of respective pairs of said series-connected switching devices.

5. An arrangement according to claim 4 wherein one of said switching devices in each of said pairs is biased to operate as said variable constant current circuit.

6. An arrangement according to claim 5 further comprising a detecting circuit connected to said junction point for detecting voltage drops across said one of switching devices, and a power supply control circuit connected to said detecting circuit for regulating the supply voltage between said first and second power supply terminals to be a predetermined value.

7. A dc motor drive circuit arrangement substantially as hereinbefore described with reference to any one of Figures 5 to 11, 11 and 13, and 11 and 14 of the accompanying drawings.

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